EXPRESS MAIL No. EU874337242US

SYSTEM AND METHOD FOR ELECTRICALLY DETERMINING POSITION AND DETACHMENT OF AN IMPLANTABLE DEVICE

Field of the Invention

The field of the invention pertains to implantable devices, and more particularly, to electrically monitoring when an implantable device is properly positioned and can be detached from a delivery system.

Background of the Invention

In many clinical situations, blood vessels are occluded or blocked off to control bleeding, prevent blood supply to tumors, and block blood flow within an aneurysm or other vascular abnormality. Aneurysms are abnormal blood filled dilations of a blood vessel wall, which may rupture causing significant bleeding. For intracranial aneurysms, the significant bleeding may damage surrounding brain tissue and cause death. Intracranial aneurysms may be particularly difficult to access and treat when they are formed in remote cerebral blood vessels. If left untreated, normal forces from blood flow through a vessel can rupture fragile tissue in the area of the aneurysm causing a stroke.

Various implants, such as vaso-occlusive devices, have been used to treat aneurysms by decreasing blood flow to the aneurysm. A vaso-occlusive device is a surgical implant that is delivered through a catheter, which is inserted through a blood vessel and placed within or near an aneurysm. Vaso-occlusive devices tend to induce blood

clotting or formation of a thrombus, which reduces blood flow to the aneurysm and limits its growth.

For instance, in one conventional assembly, a catheter or sheath is inserted through a vascular cavity, and a vaso-occlusive coil is delivered to the aneurysm site through the catheter. A delivery wire is used to advance the coil to the distal end of the catheter and to position a temporary connection, bond or detachment zone just beyond the distal tip of the catheter. The detachment zone or temporary bond is broken, thereby releasing the vaso-occlusive device.

Radiopaque markers and fluoroscopy are typically used to track the position of the detachment zone and coil attached thereto as they are advanced through the catheter. More specifically, a radiopaque marker is placed at a distal end or tip of the catheter, and another radiopaque marker is placed towards a proximal end of the catheter. The distal marker on the catheter facilitates location of the catheter tip at the aneurysm site. The delivery wire also includes a radiopaque marker. The wire and proximal catheter markers are arranged so that the wire marker is generally aligned with the proximal catheter marker when the detachment zone of the coil extends just beyond the catheter tip. When the radiopaque markers are aligned, the coil is detached from the delivery wire at the detachment zone electrolytically or by breaking a mechanical connection. The wire and the catheter are then removed, leaving the coil to occlude the aneurysm.

The positioning of detachment zones and implants, however, can be improved. For example, some conventional

systems do not properly position an implant, even when fluoroscopy is utilized, and minor positioning errors can impact the effectiveness of an implant. Thus, the detachment zones and devices should be monitored and positioned more accurately. Further, when multiple coil implants are delivered to an aneurysm, one coil can radiographicaly hide or obstruct other coils, thus making it more difficult to properly position a coil, resulting in positioning errors. Radiopaque markers used with angiographic visualization can also impair the positioning and effectiveness of various components. For example, proximal markers on the catheter typically make the catheter less flexible. Consequently, catheters with radiopaque markers may be less maneuverable through a vascular cavity, particularly through smaller, cranial and curved vessels. Further, radiopaque markers and related viewing equipment add to the costs of equipment, procedures, and training. Further, catheters are often shaped with steam. These forming techniques, however, can change the distance between radiopaque catheter markers, thus impairing the ability to properly position a coil. Proximal markers on the delivery wire can also make the delivery wire less flexible, thus increasing the likelihood that the catheter tip can be moved or forced out of the aneurysm.

A need, therefore, exists for a method and a system that can monitor the position of a detachment zone or bond and an implant attached thereto so that the implant can be accurately and predictably positioned and detached at a proper location in the body. The method and system should

also provide these enhancements without utilizing radiopaque marker components and fluoroscopy tracking techniques, which can complicate implant positioning, decrease delivery component flexibility and maneuverability, and add unnecessary equipment, costs, and training.

SUMMARY OF THE INVENTION

In accordance with one respect of the present invention is a method of positioning an implant in a body. The method includes inserting a catheter within a vascular cavity in the body, attaching the implant to a distal end of a delivery member using a temporary connection or detachment zone, such as, for example, a mechanical connection or an electrolytic connection. The delivery member, the temporary connection and the implant are advanced through a proximal end of the catheter, and an electrical condition related to the position of the temporary connection in the catheter is monitored. The electrical condition can be an electrical current, voltage, or impedance. The implant can be insulated from the temporary connection so that current passes to the temporary connection, but not to the implant. The electrical condition changes when the temporary connection reaches a predetermined location. For example, the electrical condition can change when the temporary connection reaches or exits the distal end of the catheter.

The implant is detached from the delivery member by breaking the temporary connection in response to sensing or detecting a change in the electrical condition. The

temporary connection can be broken in various manners. For example, the temporary connection can be corroded or disintegrated by providing an electrical current from a power supply through the delivery wire to the temporary connection so that the connection electrically dissolves. The connection can also be mechanically and hydraulically broken. Further, heat and Radio Frequency (RF) radiation can be used to break the temporary connection. Further, a user or a controller can initiate breaking the temporary connection. After the implant is detached from the delivery member and temporary connection, the delivery member, catheter, and any remaining portions of the temporary connection can be removed from the vascular cavity.

A monitoring or measurement device may also generate an output signal based on the changed electrical condition to indicate that the temporary connection has reached a predetermined position or location. For example, the output signal can be a visual or audio signal that is provided to a user or a control signal that is provided to a controller..

In further accordance with the present invention is a system for positioning an implant in a body. The implant can be a coil, such as a Guglielmi Detachable Coil (GDC). The coil can also be coated with a bio-reactive material to initiate formation of tissue in the aneurysm, or be a coil composed of a bio-reactive material or various non bio-active polymers. The implant can include platinum or another radiopaque material. The implant can also be a stent or a filter.

The system includes a catheter, a delivery member, such as a delivery wire, a temporary connection joining a distal end of the delivery member to the implant, and an electrical measurement device or sensor The catheter is inserted into a vascular cavity in the body. The delivery member, the temporary connection and the implant are advanced through the catheter. The electrical measurement device detects an electrical condition related to a position of the temporary connection and the device in the catheter. The electrical condition changes when the temporary connection reaches a predetermined location, such as the distal tip of the catheter.

The electrical measurement device can detect and measure various electrical conditions or parameters, such as current, voltage, and impedance. For example, when monitoring current, the measurement device compares a reference current, such as a trickle current, with a second current that is generated when the temporary connection and implant reach or exit the distal tip of the catheter. The system can also include a visual or audio indicator that generates a signal in response to the changed electrical condition. Other control signals can also be generated to indicate a change in electrical condition.

The system may also include a power supply that is coupled to the delivery member. The power supply provides an electrical current through the delivery member and the temporary connection to electrolytically break the temporary connection by, for example, corroding or disintegrating a portion of the temporary connection. The electrical measurement device can be included within the

power supply or be a separate external component. In one embodiment, an electrical circuit is completed through the delivery member, the temporary connection, the electrical measurement device, the power supply, and the body. If the temporary connection is not conductive, then a conductive wire can be connected between the electrical measurement device and the distal end of the catheter so that the electrical measurement device can detect the electrical condition through the conductive wire.

In alternative embodiments of the present invention, instead of a power supply that provides current to electrolytically break the temporary connection, other detachment inducing mechanisms can be utilized, such as sources of heat and Radio Frequency (RF) to break heat or RF sensitive bonds, for example, by melting a plastic connection. In yet a further alternative embodiment, the temporary connection can be a temporary hydraulic connection that is broken when a hydraulic element is actuated.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

FIG. 1 illustrates a system according to the present invention that utilizes an electrical measurement, detection device or sensor to monitor or identify the position of an implant and determine when the implant can be detached;

FIG. 2A is an electrical schematic that illustrates components of a system that simulates the operation of the present invention, and FIG. 2B shows a saline-filled

conductive bowl and electrical connections of Figure 2A in further detail;

FIGS 3A-E are enlarged, microscopic images of a coil implant being advanced and detached within the saline-filled bowl of FIGS 2A-B;

FIG. 4 is an electrical schematic of components of one embodiment of the system according to the present invention that includes a comparison circuit and an indication device;

FIG. 5 is an enlarged side view of one exemplary temporary electrolytic connection that can be utilized with a system of the present invention;

FIG. 6 is an enlarged side view of one exemplary temporary mechanical connection that can be utilized with a system of the present invention;

FIG. 7A-C are enlarged side views of a coil implant occupying different positions inside and outside of a catheter, and the manner of monitoring the positions of a temporary connection and an implant with the present invention; and

FIG. 8 is a flow diagram illustrating a method of monitoring a position of a temporary connection and an implant attached thereto according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, reference is made to the accompanying drawings which form a part hereof, and which show by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that

other embodiments may be utilized as structural changes may be made without departing from the scope of the present invention.

Referring to Figure 1, a system 100 according to the present invention includes a catheter or sheath 110, a pusher or delivery member 120, such as a pusher wire, a fine bore tube or other tubular member (generally delivery member 120), a temporary connection or detachment zone 130, such as a temporary electrolytic, mechanical, heat-sensitive, RF-sensitive or hydraulic connection (generally temporary connection 130), an implant 140, an insulative member 150 between the conductive temporary connection 130 and the implant 140, an electrical measurement, monitoring or detection device or sensor 160, and a device that initiates breaking of the temporary connection 130, such as a power supply 170 for providing current to break an electrolytic connection. The system 100 tracks or monitors the position of the temporary connection 130 and the implant 140 attached thereto as they are advanced through the catheter 110. The system 100 determines when the temporary connection 130 reaches or passes a predetermined position 180, such as a position 180a or a position 180b (generally 180) at which the temporary connection 130 reaches or exits the distal tip of the catheter 110. Indeed, the positions 180a and 180b are merely illustrative of various positions that can be selected.

Persons of ordinary skill in the art will recognize that the present invention can be utilized with various implants. For example, one exemplary implant is a vaso-occlusive device, such as a Guglielmi Detachable Coil

(GDC). The coil can also be coated with a bio-reactive material to initiate formation of tissue in the aneurysm, or be a coil composed of a bio-reactive material or various non bio-active polymers. The implant can also include platinum or another radiopaque material. A further exemplary implant is a stent, such as a self expanding stent, a balloon expandable stent, a coated or a non-coated stent, a covered or partially covered stent, a high density braid stent, and a stent covered in-situ. Further, the implant can be a filter, such as a filter to capture embolic debris. In this specification, an implant refers to these exemplary implants and other suitable detachable implants that can be utilized with the present invention.

Persons of ordinary skill in the art will also recognize that the present invention can be utilized to treat various conditions, including aneurysm, tumors and other vascular malformations. This specification, however, refers to a system and method of monitoring or tracking an implant for treating an aneurysm for purposes of explanation and illustration, but the invention is not so limited.

The catheter 110 is made of a generally insulative or non-conductive material and defines an inner lumen or cavity 112 and has a proximal end 114 and a distal end 116. The distal end 116 is advanced through a vascular cavity or space 192, such as an artery, vessel, vein, aneurysm, arteriovenuous fistulas, or other vascular malformation in the body 190. The conductive delivery member 120 has a proximal end 122 and a distal end 124. The conductive temporary connection 130 detachably or releasably connects

the distal end 124 of the delivery member 120 and the implant 140, with an insulative member 150 there between. As a result, the catheter 110 and the insulative member 150 form an "insulative chamber" that prevents or minimizes the amount of current that flows through the delivery member 120 when the member 120 is confined to the catheter lumen 112.

An initial electrical condition or parameter 162 in the circuit completed through the body 190 is detected by the measurement device or sensor 160. Exemplary electrical conditions 162 include a current, a voltage, and an impedance. While various electrical conditions 162 can be monitored, measured or detected, this specification refers to current for purposes of explanation. Further, while the measurement device 160 is shown as part of the power supply 170 in Figure 1, in an alternative embodiment, the measurement device 160 is separate from the power supply 170.

The magnitude of the current 162 is related to the position of the temporary connection 130 and the implant 140 attached thereto as they are pushed through the lumen 112 of the catheter 110. For example, the current 162 may indicate when the temporary connection 130 reaches or exits the distal tip 116 of the catheter 110.

More specifically, the power supply 170 provides a voltage V_1 that results in a small initial or trickle current I_1 162 flowing through the circuit completed through the patient body 190. The initial trickle current I_1 162 results from the high resistance of the insulative catheter 110 and insulative member 150, which limit current flow

when the conductive detachment zone 130 is located within the catheter 110.

As the delivery member 120, temporary connection 130 and implant 140 are pushed through the catheter lumen 112, the temporary connection 130 reaches or passes a predetermined location 180, such as the distal tip 116 of the catheter 110. As a result, the conductive temporary connection 130 exits the "insulative chamber" in the catheter 110 and contacts blood in the vascular space 192 in the body 190. Since the blood and the body 190 are conductive than the insulative elements, a larger, second current I_2 flows through the circuit formed by the delivery wire 120, the temporary connection 130, the body 190, and the measurement device 160. The measurement device 160 detects this larger, second current I_2 164 and issues an output signal, such as an audio, visual or control signal or triggers a device to generate an audio, visual or control signal, indicating that the detachment zone 130 has reached or passed the distal tip 116 of the catheter 110. For example, a Light Emitting Diode (LED), buzzer, or a speaker can be activated in response to the changed electrical condition.

In other words, the change from the smaller current I_1 162 to the larger current I_2 164 indicates that temporary connection 130 and implant 140 are properly positioned so that the implant 140 can be released into the aneurysm.

The output signal can be provided to a user or to a controller. For example, the output signal can indicate to a user that the temporary connection 130 and the implant 140 are properly positioned and may prompt or notify a user

to manually initiate breaking of the temporary connection to detach the properly positioned detachment zone 130 and implant 140. In an alternative embodiment, an output signal can also trigger a controller to automatically initiate breaking of the temporary connection.

The implant 140 can be detached from the detachment zone or temporary connection 130 in different ways depending on the particular implant 140 and connection 130 utilized. For example, as shown in Figure 1, the power supply 170 can provide a current (e.g., a direct current (DC)) through the delivery member 120 to the temporary connection 130 to electrolytically break the connection 130, thereby releasing the implant 140 to occlude the aneurysm. The invention, however, is not limited to electrolytic temporary connections.

In an alterative embodiment, the temporary connection 130 can be mechanically broken. In yet a further alternative embodiment, the temporary connection 130 can be a heat-sensitive or Radio Frequency (RF) sensitive connection, such as a plastic coupling, that can be melted or broken when exposed to sufficient heat or RF radiation. In yet a further alternative embodiment of the present invention, the temporary connection 130 is a hydraulic connection that can be broken by a hydraulic actuation device. Thus, with these alternative embodiments, instead of using current from a power supply 170 to electrolytically break a connection 130, other detachment inducing mechanisms can be utilized, such as sources of heat, RF, and hydraulic fluid. This specification, however, refers to electrolytic temporary connections and a

power supply for purposes of explanation and illustration, but the invention is not so limited.

With the present system 100, the position of the temporary connection 130 and the implant 140 attached thereto can be accurately monitored. Thus, the system 100 of the present invention provides an accurate and predictable manner of positioning and detaching an implant 140 without resorting to radiopaque marker components and fluoroscopy tracking.

Having described a system of the present invention and the manner in which the system is utilized, following is a description of tests and test arrangements that simulate and demonstrate the system and method of the present invention. The specification then describes further details regarding various aspects of components of the present invention and a method of electrically monitoring the position of a temporary connection or detachment zone and an implant attached thereto.

Figures 2A-B illustrate one test arrangement 200 that simulates how the present invention operates when utilized in a vascular space in a body. In this test, the power supply is an alternating current (AC) generator 210, the monitoring device or sensor is a digital volt/current meter or multimeter 220 set to detect and measure AC, and the implant is a Guglielmi Detachable Coil (GDC) 230.

A conductive wire 240, which simulates a conductive temporary connection, is connected to an insulative element 235. A conductive, stainless steel bowl 250 filled with about 200 ml of saline solution 252 (or other conductive

solution) simulates a vascular space with a non-insulative or conductive fluid, such as an aneurysm filled with blood.

A positive input 222 of the multimeter 220 is coupled to the bowl 250 via wire 254, a negative or ground pole 214 of the AC generator 210 is coupled a negative or ground pole 224 of the multimeter 220 via wire 223, a positive output 212 of the AC generator 210 is coupled to the proximal end of the wire 240, and the distal end of the wire 240 is connected to the insulative member 235, which is connected to the GDC 230.

The distal end of the GDC 230 was advanced through a catheter 260 into the saline 252, and the multimeter 220 detected a small trickle current of about 0.011 mA flowing through the circuit. The wire 240, insulative element 235, and GDC 230 were then advanced further into the saline 252. Eventually, the GDC 230 and insulative element 235 were advanced into the saline 252 so that the conductive wire 240 exited the distal end of the catheter 260 and eventually contacted the saline 252. When saline contact occurred, the current increased from the initial trickle current of about 0.011 mA to a second, larger current of about 1.122 mA. The second, larger current resulted from reduced resistance as a result of the conductive wire 240 contacting the saline 252. In other words, the insulative element 235 no longer inhibited the current, thus permitting a larger current to flow through the circuit. This test was conducted with various AC voltage and frequency settings to verify these results, for example, the AC generator 210 was set to 300 mV at a frequency of 90 kHz.

Figures 3A-E show the wire 240, insulating element 235, and GDC 230 components being advanced through the catheter 260 and into the saline 252. The distal end of the catheter 260 was submerged in the saline 252 so that as the components contacted the saline 252 as they exited the distal tip of the catheter 260. The advancement of the components was observed under a microscope.

Figures 3A-B show the GDC 230 being advanced into the saline 252, but not so far that the conductive wire 240 contacted the saline 252. As a result, only the low, trickle current of about 0.011 mA flows through the circuit due to the resistance of the insulative member 235 and catheter 210. As shown in Figures 3C-E, as the components were advanced further, the conductive wire 240 eventually exited the distal tip of the catheter 260 and contacted the saline 252. As a result, more current flows through the wire 240, saline 252, and the bowl 250 due to the lower resistance of the wire 240. This increased current is detected by the multimeter 220. These simulations and test results demonstrate that a conductive temporary connection or detachment zone, placed initially in an insulative environment or chamber and exiting the distal tip of the catheter to be part of a conductive path, triggers a change in an electrical parameter, such as current, through the circuit. This change can be used to activate an indicator to notify a user or serve as a signal for a control circuit.

For example, Figure 4 illustrates one embodiment of a monitoring system 160 that utilizes a comparison circuit 420 and a buzzer 450 to indicate the position of the

temporary connection. In this embodiment, the positive output 212 of the AC generator 210 is coupled to a patient lead 400 through a resistor 410 (e.g., a 5 KΩ variable resistor) and a wire 412. The positive output 212 is also coupled to a negative or reference input 424 of a comparator 420, such as an operational amplifier, through a resistor 425 and a wire 428. Thus, both the AC generator 210 and the comparator 420 are connected to the first patient lead 400. A positive input 422 of the comparator 420 is coupled to a second patient lead 402 and to the negative input 426 of the comparator through resistors 430 and 432, forming a feedback loop. As a result, when the patient leads 400 and 402 are connected to a patient body to complete the circuit (e.g., the body is one of four legs of a Wheatstone bridge) and the current is provided to the comparator input 422 via the feedback loop.

The reference value or threshold of the comparator 420 can be set so that the initial trickle current or initial state corresponding to the temporary connection 230 not contacting the body or blood in an aneurysm results in a low output 426. At this stage, the low output 426 of the comparator 420 would not activate an indicator, such as a buzzer 440. As the temporary connection 130 advances further and exits the catheter or contacts the body or blood, then the input current 422 is larger than the reference or threshold 424. As a result, the output 426 will change from low to high, and the output 426 can activate the buzzer 440 to inform a user that the implant 140 is properly positioned and can be detached from a delivery system. The user may then manually initiate

detachment of the implant or detachment can be automatically initiated with a controller.

Having described the components of embodiments of the system of the present invention and the manner in which the system operates, following are more detailed descriptions of exemplary components of the present invention, and the manner in which the components are designed with conductive and insulative sections that trigger a change in an electrical condition as they are inserted through a catheter and into a patient body.

Referring to Figure 5, the wire 120 disposed in the catheter 110 may be a stainless steel wire laminated with Teflon®. An exemplary wire 120 has a diameter of approximately 0.010-0.020 inch (0.254-0.508 mm) and a length of about 50-300 cm. A first bonding location 500 may be covered with an insulating Teflon laminate 505, which encapsulates the underlying portion of wire 120 to prevent contact with the blood when being inserted through the catheter 110.

A stainless steel coil 510 is attached or bonded to the wire 120 at the first bonding location 500. For example, the stainless steel coil 510 can be soldered, welded or adhered to the wire 120. The distal end of stainless steel coil 500 is attached to the distal end of the wire 120 and to the proximal end of an implant 140, such as a platinum GDC coil, at a second bonding location 515.

One exemplary GDC coil forms a spiral or helix typically between 2 to 10 mm. in diameter. The helical envelope formed by a secondary coil 520 may be cylindrical

or conical. Like the wire 120 and the stainless steel coil 510, the coil 520 is between approximately 0.010 and 0.020 inch (0.254-0.508 mm) in diameter. The coil 520 is soft and its overall shape can be deformed. When inserted within the catheter 110, the coil 520 is straightened to lie axially within the catheter 110. Once disposed out of the distal tip 116 of the catheter 110, the coil 520 forms a deformable shape and may be shaped to the interior shape of the aneurysm.

Referring to Figure 6, a further exemplary implant 140 is a wire 600 that has an end portion 605 covered with a Teflon® laminate 610. The wire 600 is attached by means of a mechanical coupling 615 to a platinum coil 620. The platinum coil 620 has a plurality of filaments 625 extending there from. For example, in a small vessel, hair 625 lengths of up to 1 mm can be utilized. The hairs 625 pack, fill or at least impede blood flow or access in the vascular cavity. The coil 620 has sufficient length and flexibility so that it can be inserted or coiled loosely into an aneurysm or other vascular cavity.

The tip 104 may also be mechanically separated from the wire 120 by various other temporary connections 130. One alternative connection 130 is a spring loaded mechanical clasp (not shown). The clasps are retained on the tip as long as the clasps remain inside of the catheter 110, but spring open and release tip 104 when extended from the catheter. A further alternative connection 130 is a nonresilient mechanical ball and clasp capturing mechanism. In yet a further embodiment, the wire 120 and the tip portion 625 screw into each other and can be unscrewed from

each other by rotation of the catheter or wire with respect to tip 104. Persons of ordinary skill in the art will recognize that other mechanical detachment configurations can be utilized.

In use, as shown in FIGS. 7A-C, the coil implant 140 is used as an electrical anode while the cathode is a skin electrode 700 typically conductively applied to the groin or scalp. In an alternative embodiment, the catheter 110 is supplied with an end electrode coupled to an electrical conductor disposed along the length of catheter 110. A wire is led back to voltage source 170 so that the ring electrode is used as the cathode instead of an exterior skin electrode 700. This specification, however, refers to a portion of the body serving as a cathode for purposes of explanation and illustration.

Figures 7A-C illustrate the wire 120, temporary connection or detachment zone 130, insulative element 150 and coil 140 components being advanced through the catheter 110. The distal end 116 of catheter 110 is placed into a neck 705 of the aneurysm 710. In Figure 7A, the components are still contained within the insulative catheter 110. Thus, the electrical condition or current 162 is the smaller, trickle current I_1. When the coil implant 140 is disposed within the catheter 110, it lies along the longitudinal lumen 112 defined by catheter 110.

Figure 7B shows the wire 120 being advanced, thereby feeding the tip 142 of the coil 140 into the aneurysm 710, and the bonding location or temporary connection reaching the distal tip 116 of the catheter 110. As a result, a portion of the stainless steel coil 510 (Figure 5) of the

temporary connection 130 is exposed beyond the distal tip 116 of catheter 110. The temporary connection 130 contacts blood in the aneurysm 710, thereby completing a circuit with less resistance. Thus, the current increases from I_1 162 to I_2 164, and this change in electrical condition indicates that the temporary connection or detachment zone 130 has reached or passed the distal tip 116 of the catheter. Thus, the coil 140 is properly positioned and can be detached.

In response to this change in the monitored electrical condition, the monitoring or measuring system 160 provides an output signal to a user. The user can manually initiate detachment of the device, or the output signal can automatically trigger the power supply 170 to provide a direct current (DC) through the wire 120 to the temporary connection 130. An occlusion is eventually formed as a result of the reduced blood flow to the aneurysm. As shown in Figure 7C, after the aneurysm is occluded, the tip 142 and coil implant 140 are detached from the wire 120 by electrolytic disintegration of at least one portion of stainless steel coil 510 of the detachment zone or bond 130. For example, the coil 140 can be detached from the temporary connection 130 by continued application of current for a predetermined time when the stainless steel 510 is exposed to blood; or by movement of the wire 120 to expose stainless steel 510 to blood followed by continued current application for a predetermined time. In the illustrated embodiment this is accomplished by continued application of current until the total time of current application is almost approximately four minutes.

As a result, at least one portion of stainless steel coil 510 will be dissolved through by electrolytic action, typically within 2 minutes, usually less than one minute. . After separation by electrolytic disintegration, the wire 120, catheter 110 and the remaining portion of stainless steel coil 510 still attached to the wire 120 are removed from vascular space 192, leaving the coil 140 in the occluded aneurysm 710. It will be appreciated that the time of disintegration may be varied by altering the dimensions of the portions of the wire and/or the current.

As previously discussed, different temporary connections may utilize different mechanisms to initiate breaking of the temporary connection. Further, various other controllable coils and implants can be used with the present invention. Referring to Figure 8, following is a summary of a method of monitoring a position of an implant. Various method steps have been previously described with respect to the operation and function of the system related to Figures 1-8.

In stage 800, a catheter is inserted into a vascular cavity. In stage 805, an implant, such as a vaso-occlusive device, a GDC, a stent or another suitable implant, is attached to a delivery member having a temporary connection. An insulative member may be placed between the temporary connection and the implant. In stage 810, the delivery member with the temporary connection, the insulative member and the implant are advanced through the lumen of the catheter. In stage 815, an electrical condition related to the location of the temporary

connection is monitored with a sensor or a suitable measurement device.

In stage 820, a determination of whether the electrical condition has changed is made. If the electrical condition has changed, then the temporary connection has reached a predetermined location, e.g., the distal end or tip of the catheter, and the method proceeds to stage 825. If the electrical condition has not changed, then the components are advanced further into the catheter in stage 810 and the system continues to monitor the electrical condition at stage 815.

Continuing with stage 825, an output signal indicating a change in electrical condition is generated. The output signal indicates that the temporary connection and the implant are properly positioned. The output signal can be provided to a user in stage 830 or to a controller at stage 835. If the output signal is provided to a user at stage 830, then the user can decide whether to break the temporary connection and detach the implant at stage 840. The user can also advance or adjust the delivery member as needed before breaking the connection. If the user decides to detach the implant, then in stage 845, the user initiates detachment of the implant by breaking the temporary connection.

If the output signal is provided to a controller in step 835, then the controller can be configured to initiate breaking of the temporary connection in step 845 immediately or after a delay, if necessary.

At stage 850, the system components can be removed, leaving the implant to occlude the aneurysm site.

Having described a system and a method for monitoring the position of a implant both inside and outside a delivery catheter, persons of ordinary skill in the art will recognize that the above system and method can be modified in various ways to perform the same monitoring functions. For example, the present invention can be used with various implants, and a vaso-occlusive GDC coil is merely illustrative of various suitable implants. Further, other monitoring systems and configurations can be utilized to determine an electrical condition, such as current, voltage, resistance, impedance, and other conditions as needed, to monitor the position of a temporary connection or detachment zone and an implant.

Although references have been made in the foregoing description to various embodiments, persons of ordinary skill in the art will recognize that insubstantial modifications, alterations, and substitutions can be made to the described embodiments without departing from the invention as recited in the accompanying claims.